MECHANICAL DESIGN OF NEW DUAL PINHOLE MINI-BEAM COLLIMATOR WITH MOTORIZED PITCH AND YAW ADJUSTER PROVIDES LOWER BACKGROUND FOR X-RAY CRYSTALLOGRAPHY AT GMCA@APS

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With my colleagues at GM/CA CAT
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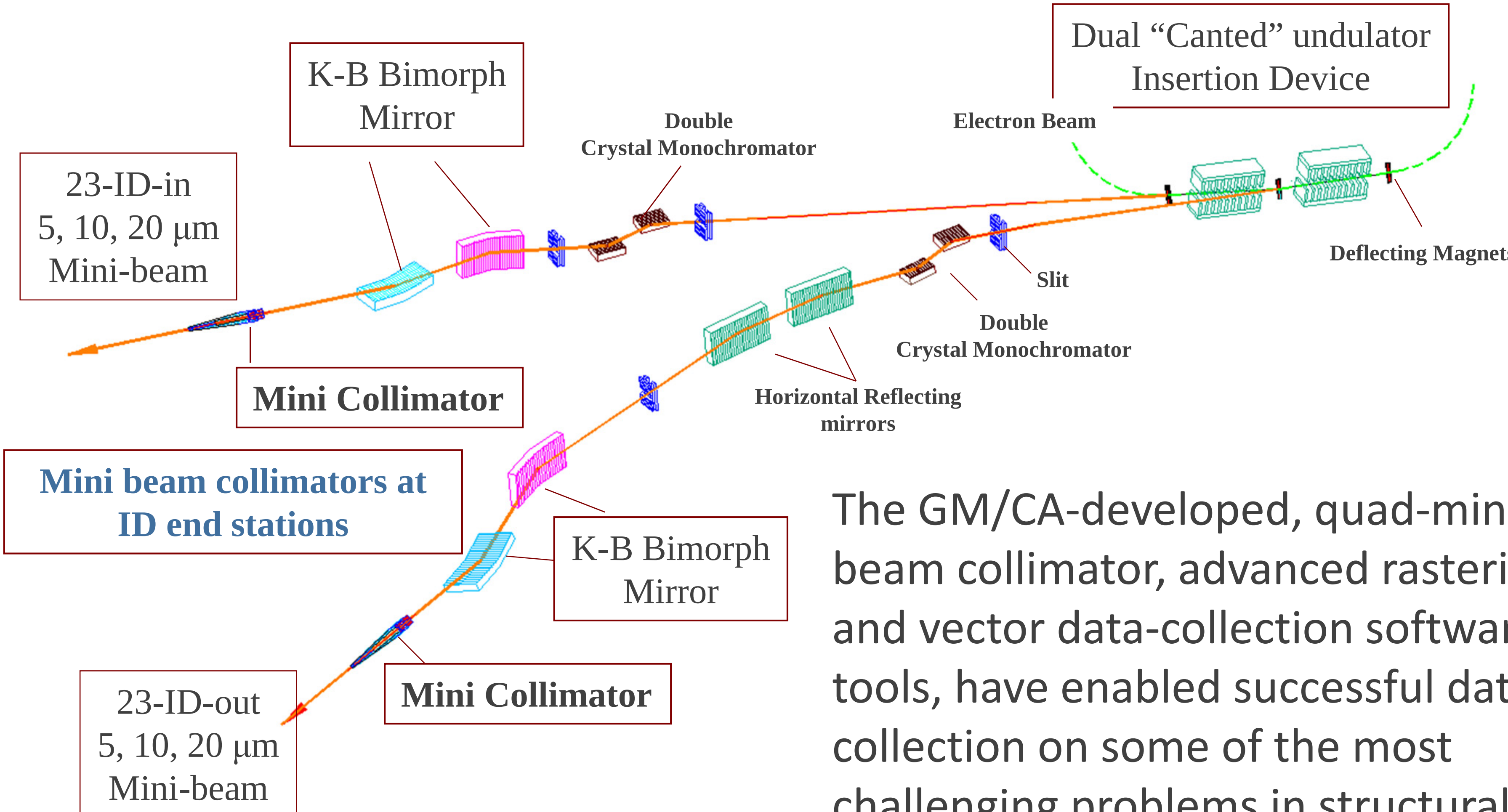
2016 MEDSI - 9th International Conference on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation.
Barcelona Spain, September 15, 2016

Outline

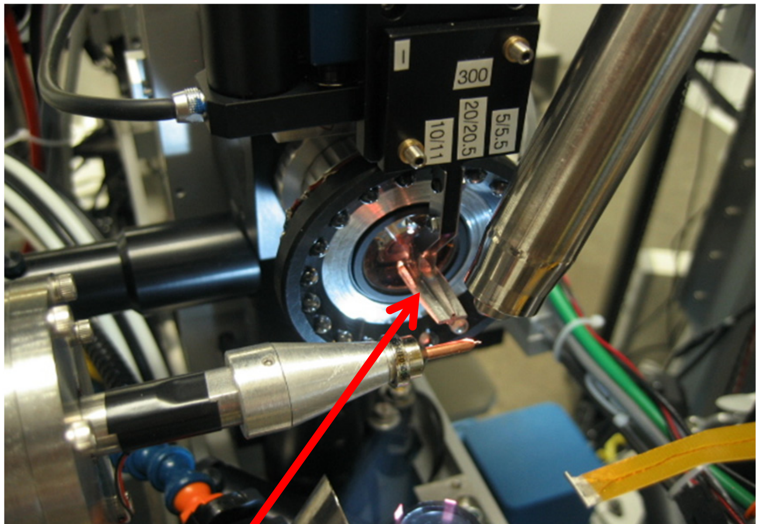
- GMCA mini-beam, rastering and vector data-collection tool
- Design history of compact mini beam collimators
- New mini-beam collimator with small exit apertures provides lower background
- Collimator positioning system with motorized pitch and yaw adjuster

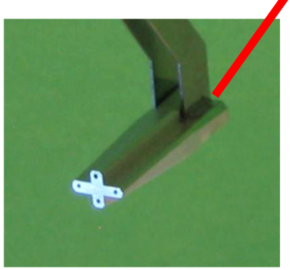
GM/CA-CAT dual canted undulator beamlines at the APS



The GM/CA-developed, quad-mini-beam collimator, advanced rastering and vector data-collection software tools, have enabled successful data collection on some of the most challenging problems in structural biology.

Original quad-mini-beam collimator





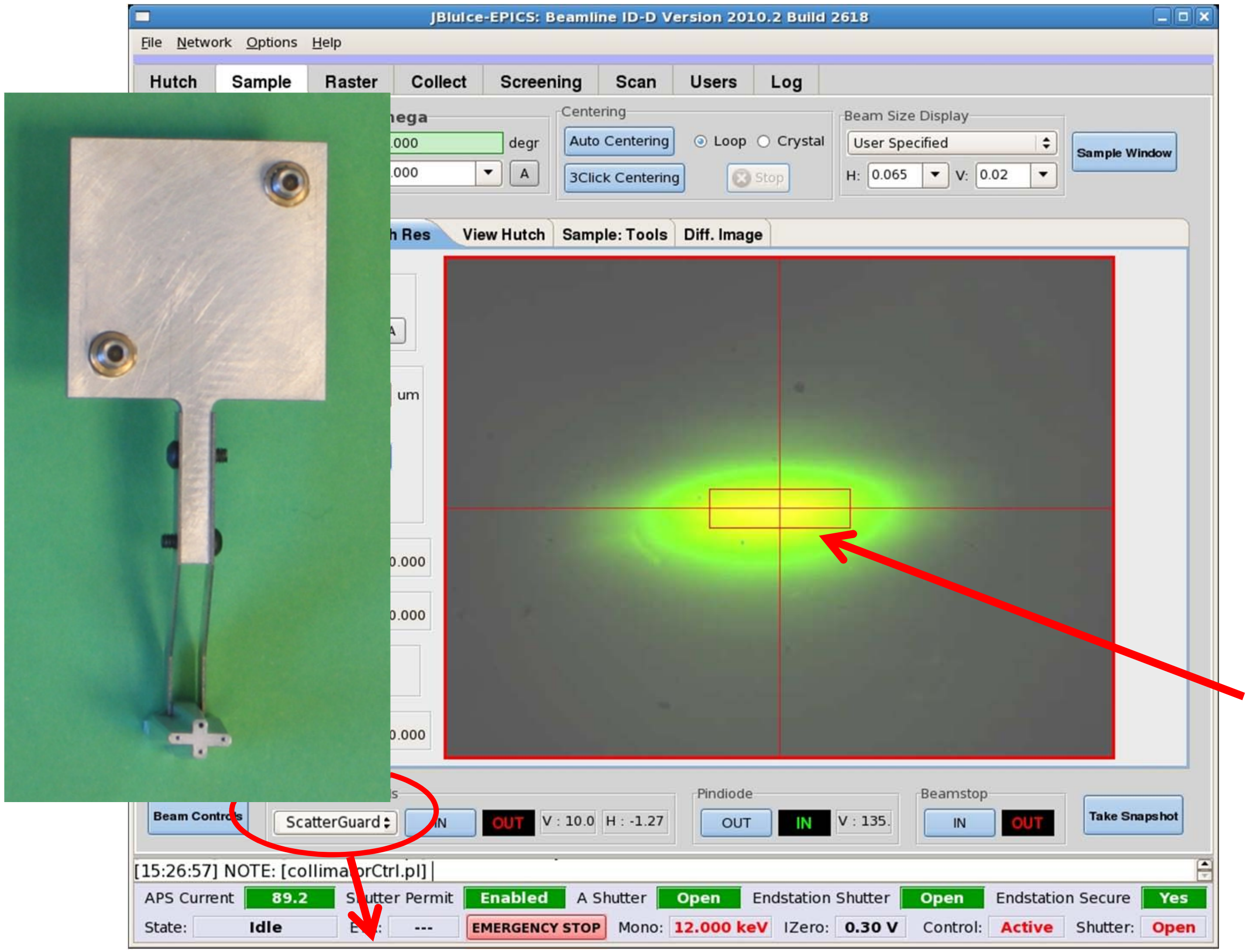
Quad mini-beam collimator: 5, 10, 20-µm beams and 300- µm scatter guard

A novel hard X-Ray Quad Collimator system for micro-crystallography experiments in structural biology

Key technical advantages include highly reproducible, automated exchange between various mini-beams and the full focused beam within a few seconds

Mini-beam collimator enables Micro-crystallography experiments on standard beamlines

Rapid beam size selection – pioneered at GM/CA



JBluIce-EPICS GUI

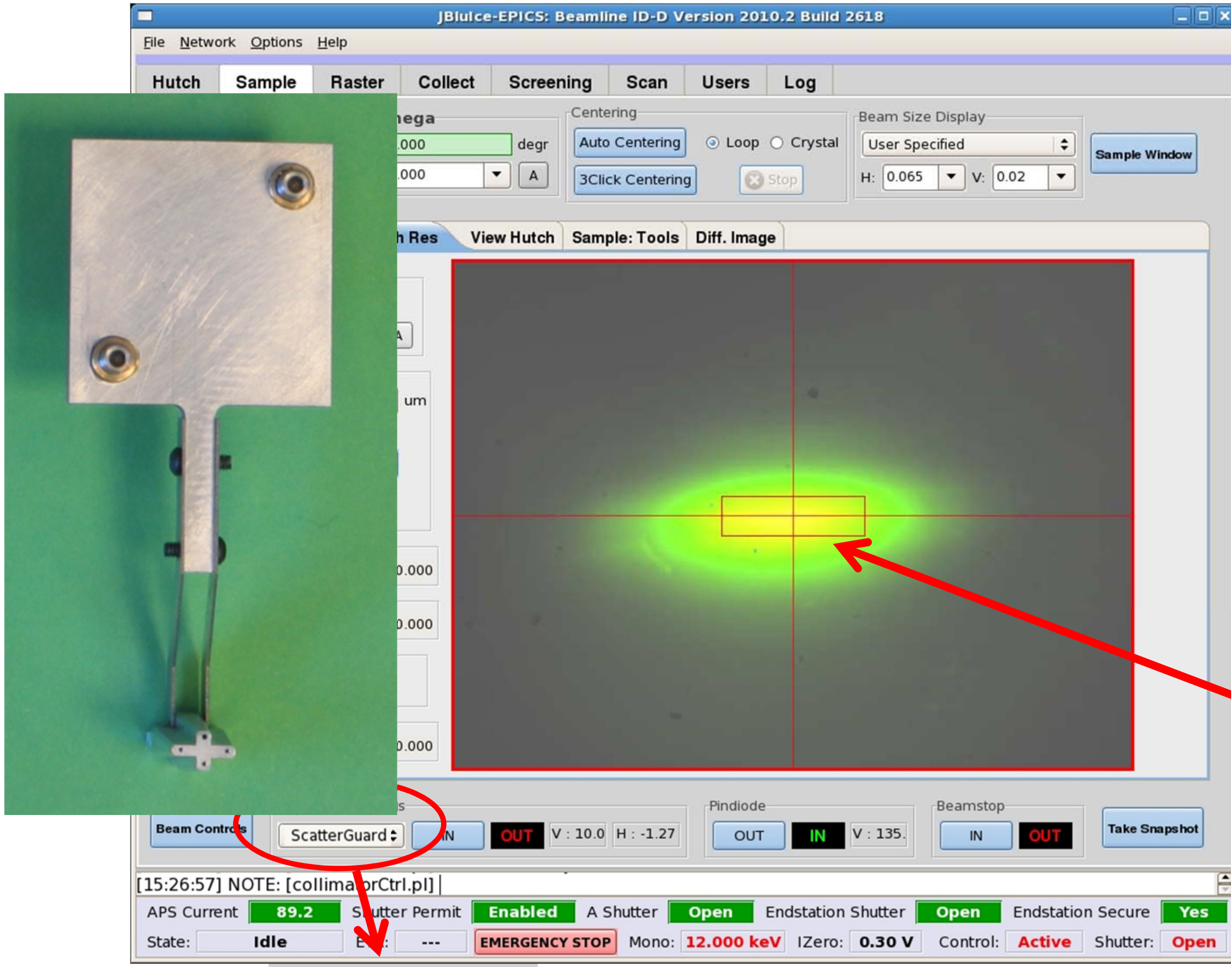
Beam size FWHM (μm)	Intensity (Ph./sec)
20 x 65	2.0 x 10^{13}
20 ∅	1.0 x 10^{12}
10 ∅	5.2 x 10^{11}
5 ∅	2.0 x 10^{11}

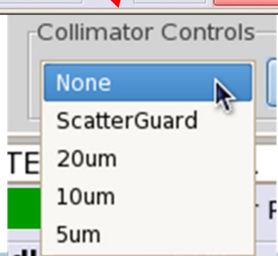
Image of beam at sample position on YAG crystal

Quad mini-beam collimator

- match beam and crystal size
- use small beam to probe large crystal

Rapid beam size selection – pioneered at GM/CA





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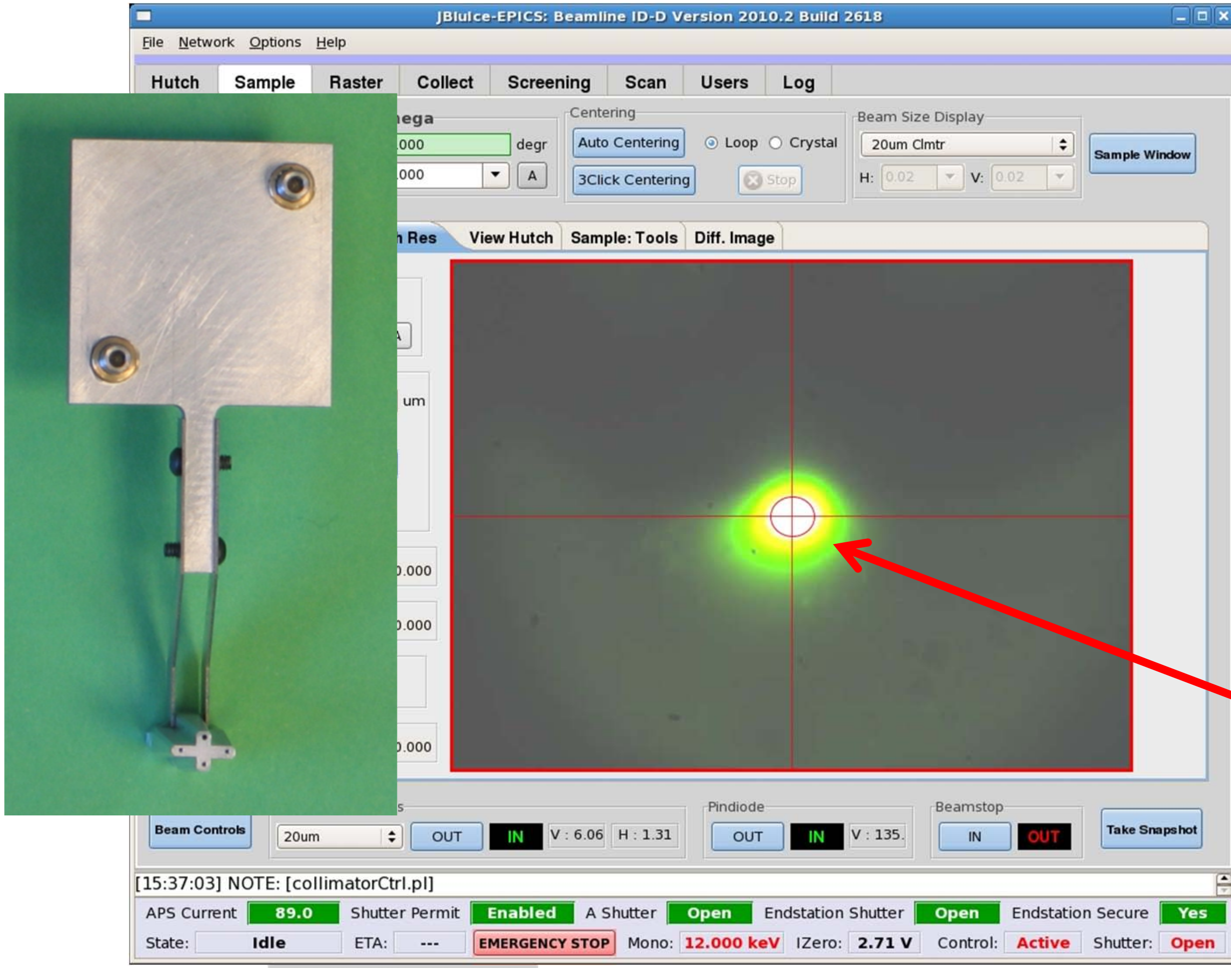

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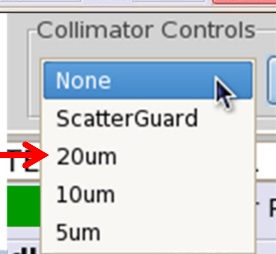

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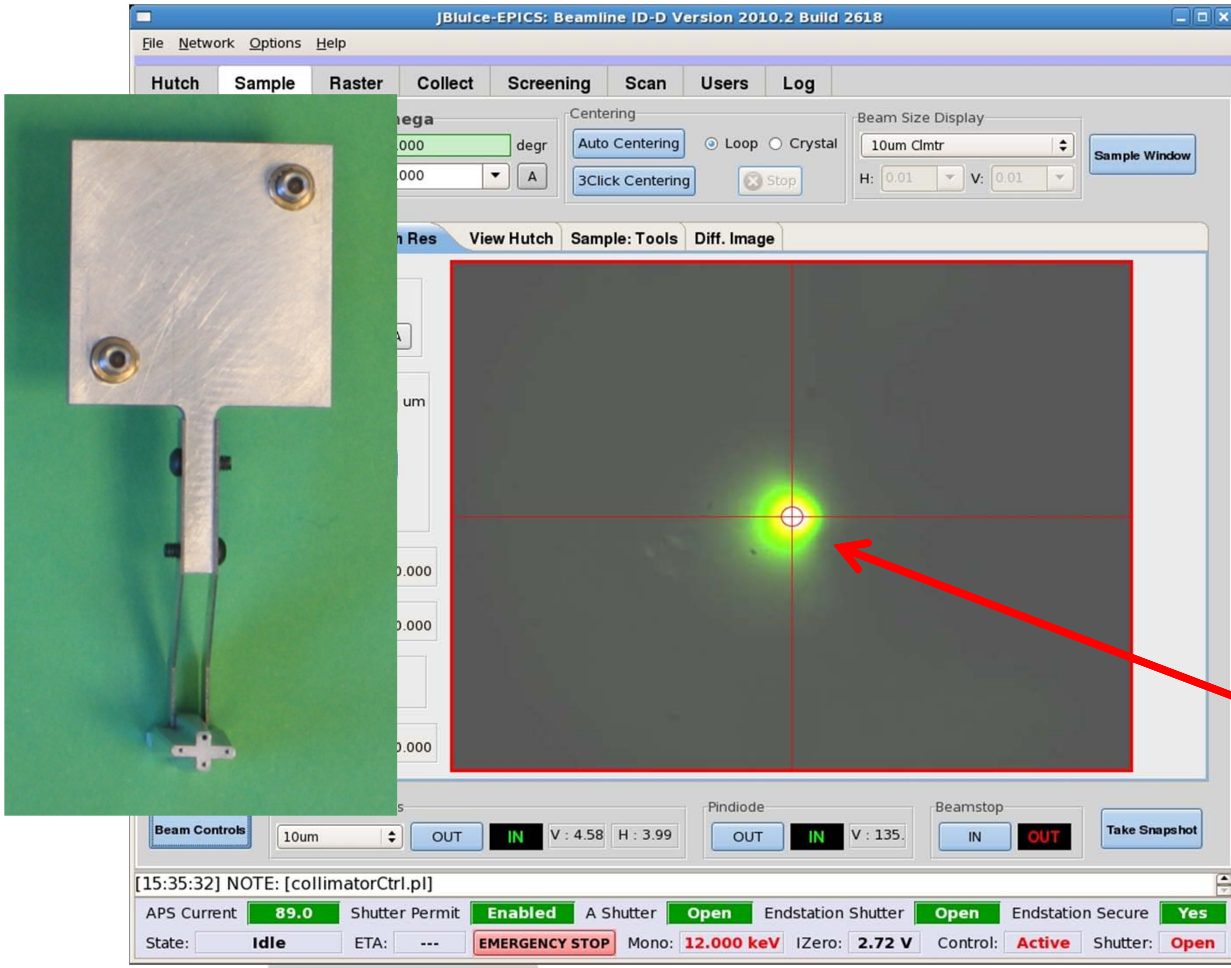
Rapid beam size selection – pioneered at GM/CA



JBluIce-EPICS GUI

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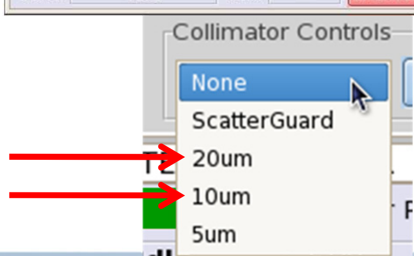

Quad mini-beam collimator

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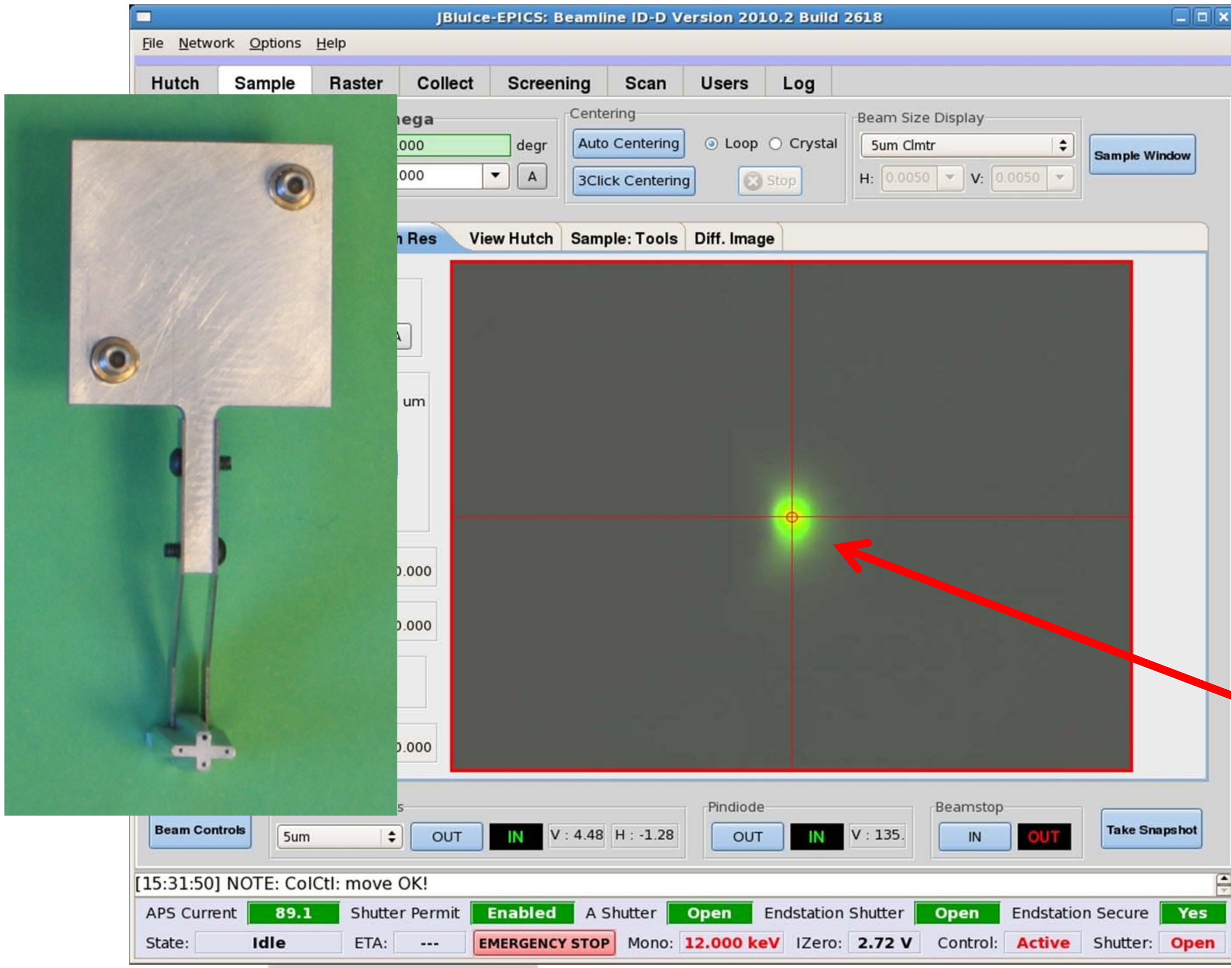
Rapid beam size selection – pioneered at GM/CA



JBluIce-EPICS GUI

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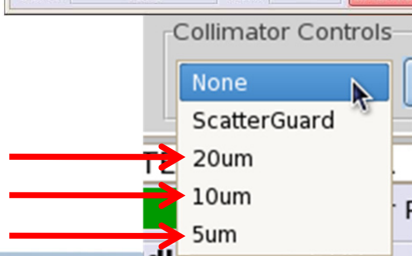
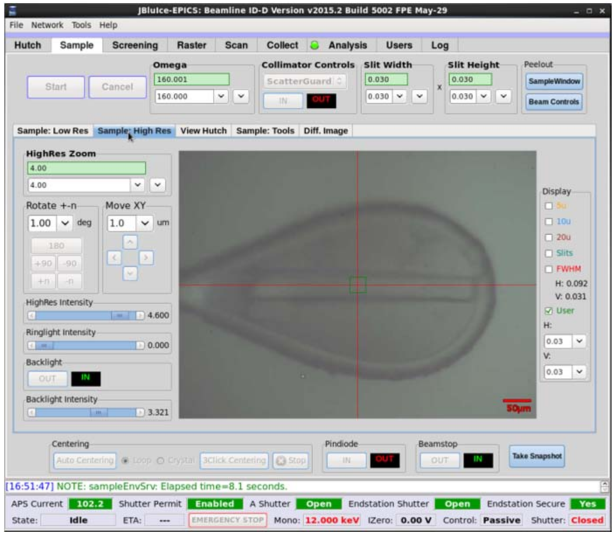


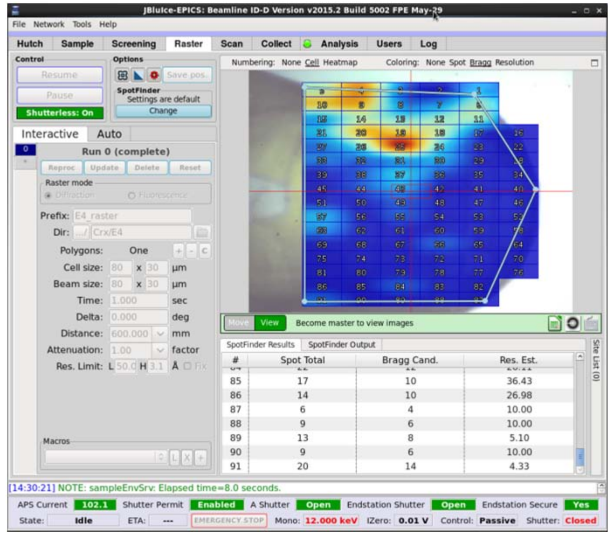
Quad mini-beam collimator

- match beam and crystal size
- use small beam to probe large crystal

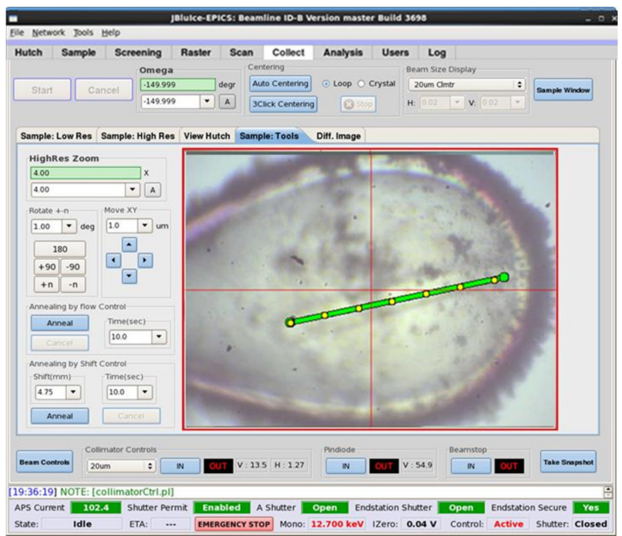
Advanced rastering and vector data-collection software tools



Finding/centering sample crystals

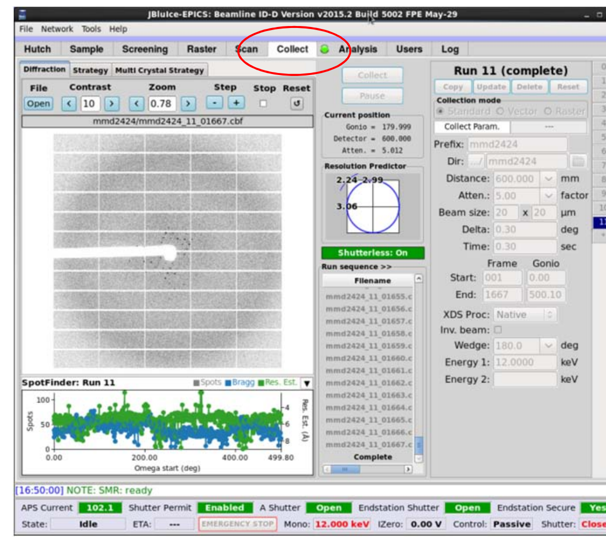


Rastering/mapping crystal quality



Vector data collection.

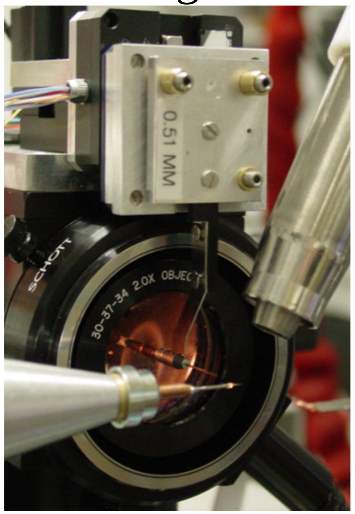
Data-collection tab

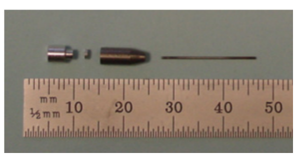


Mark, Nukri, Craig and Sergey

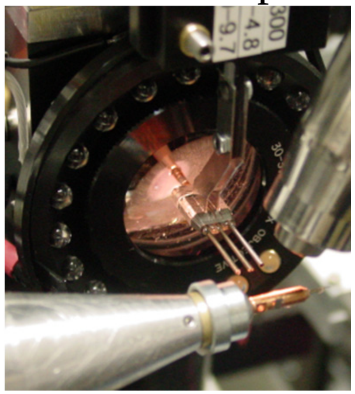
Design history of compact mini beam collimators

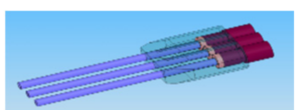
Feb 2007
single



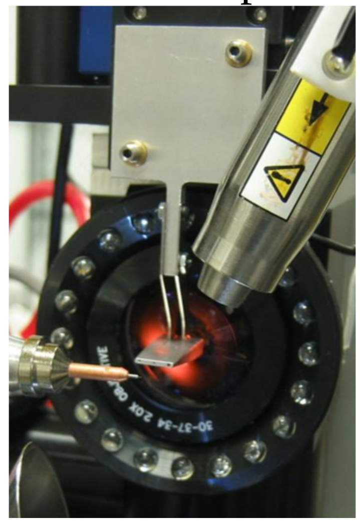


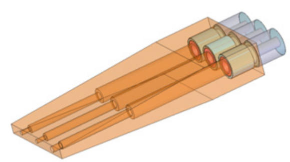
Feb 2008
dual and triple



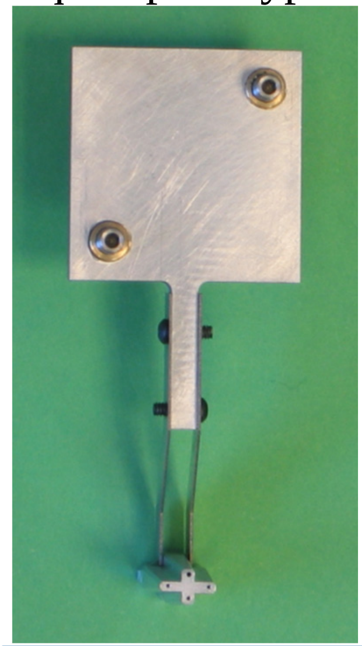


Feb 2009
robust triple



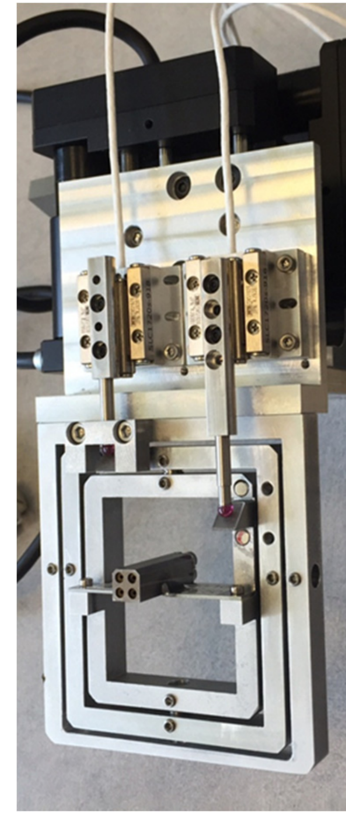


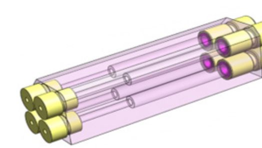
Jul 2009
quad prototype



5, 10, 20 micron
mini-beam or
scatter guard

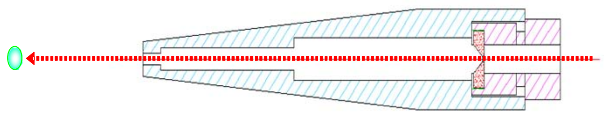
April 2015
Dual, quad
Pitch and yaw

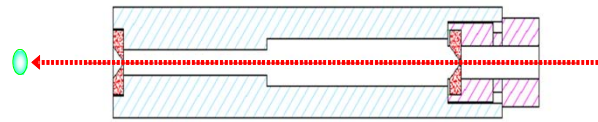


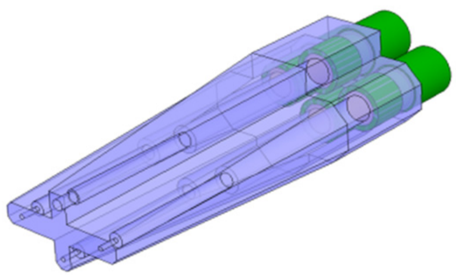


Motivation
- Provide small beam to match diffracting volume
- Stable beam
- Low background scatter
- Sample visualization

2015 developing dual-pinhole collimator with small exit apertures provides lower background

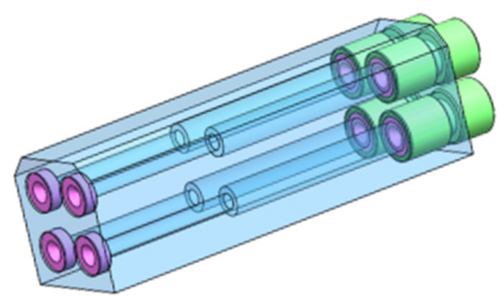






Improved

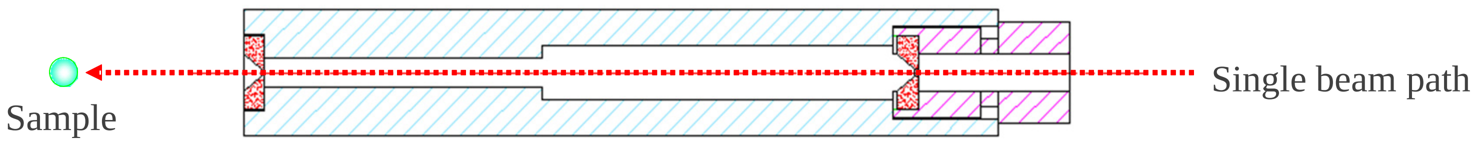
Reduce Background

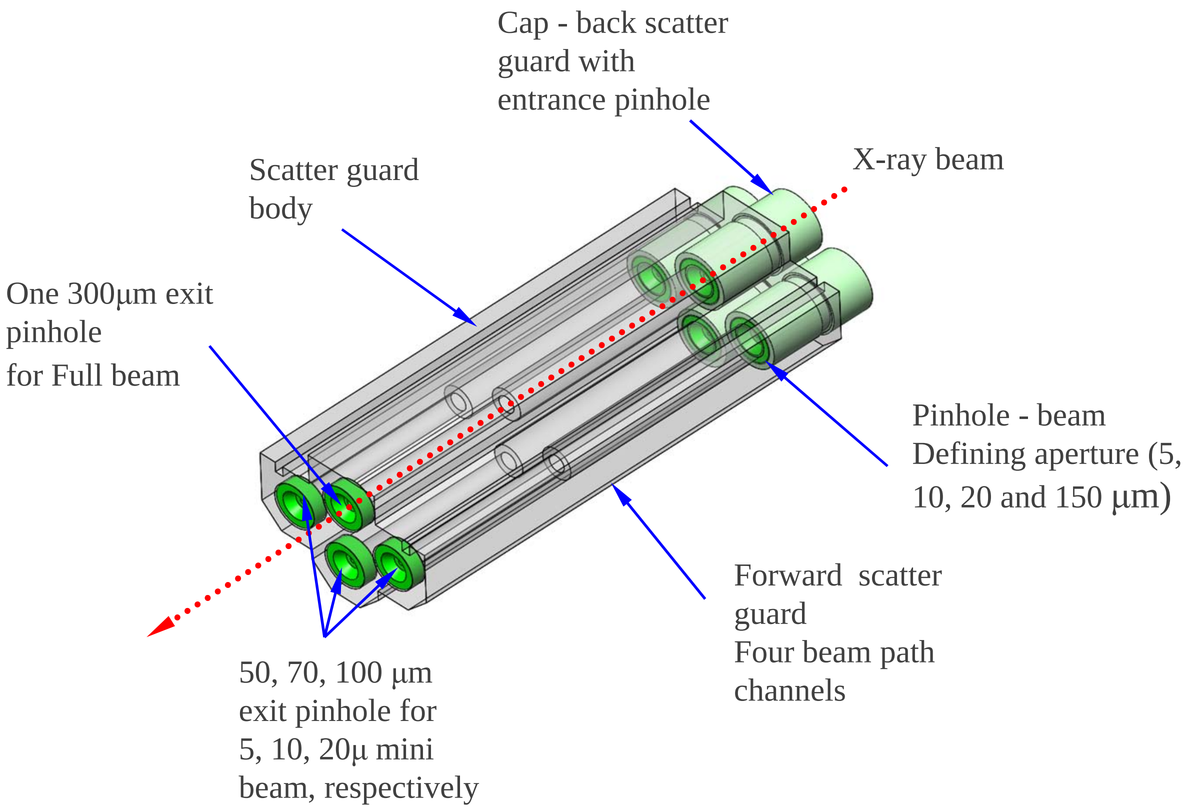


Collimator	Beam Defining pinhole (μm)	Exit Aperture (EDM) (μm)
1	5	250 EDM
2	10	250 EDM
3	20	250 EDM
4	300	600

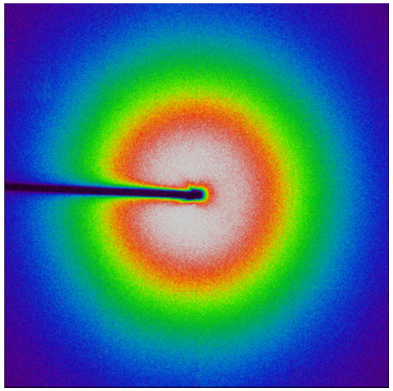
Collimator	Beam Defining pinhole (μm)	Exit-pinhole Aperture (μm)
1	5	50
2	10	70
3	20	100
4	150	300

New Dual-pinhole Quad mini-beam collimator

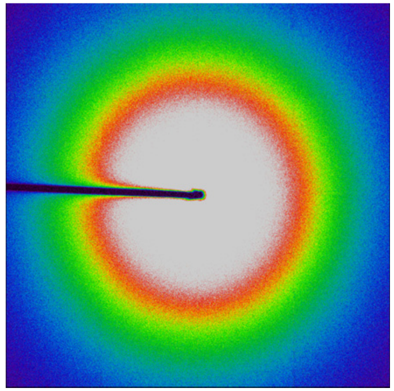




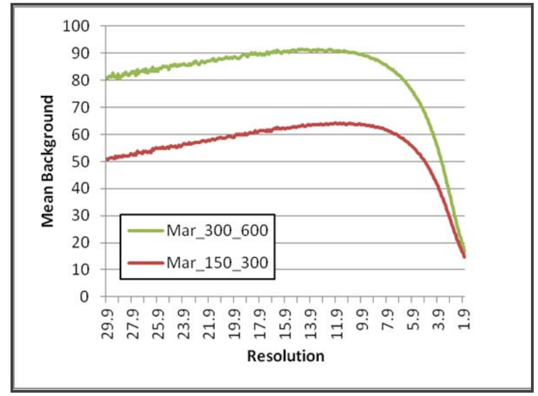
Background - Full beam: 150/300 Vs 300/600



150µm/300µm

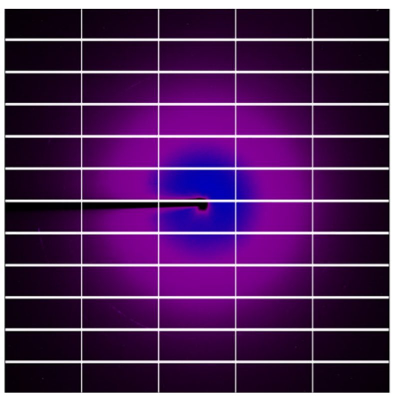


300µm/600µm

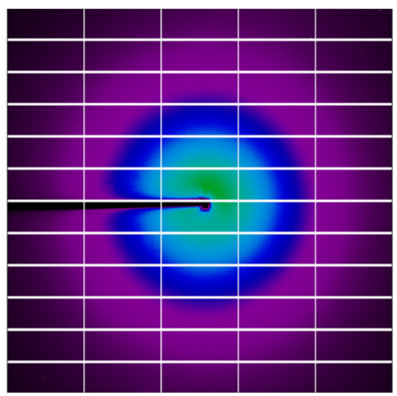


Background scattering
Decreased by 27%

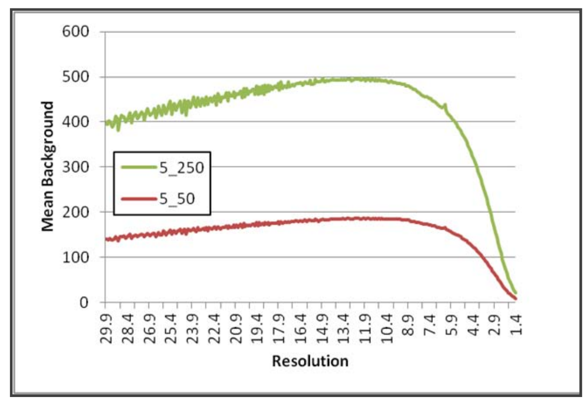
Background scatter: 5/50 Vs 5/250



5µm/50µm

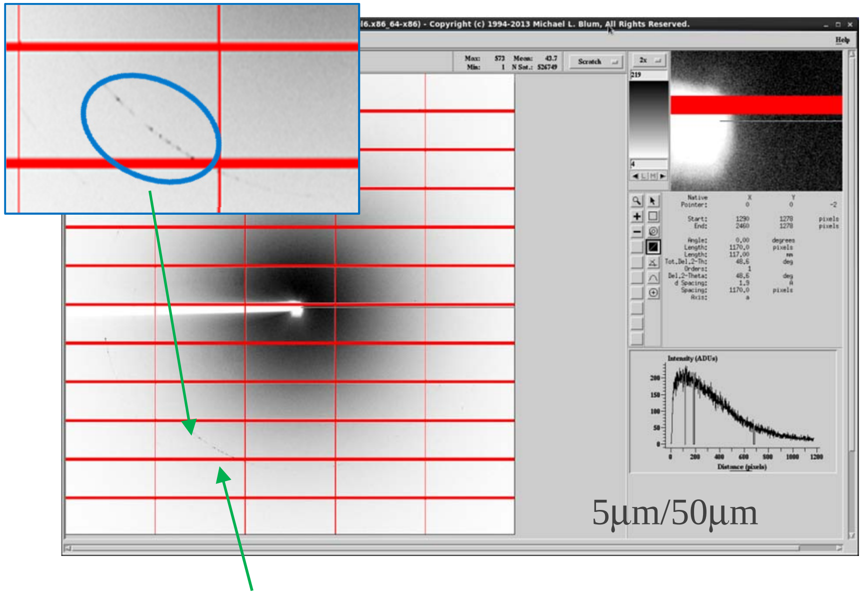


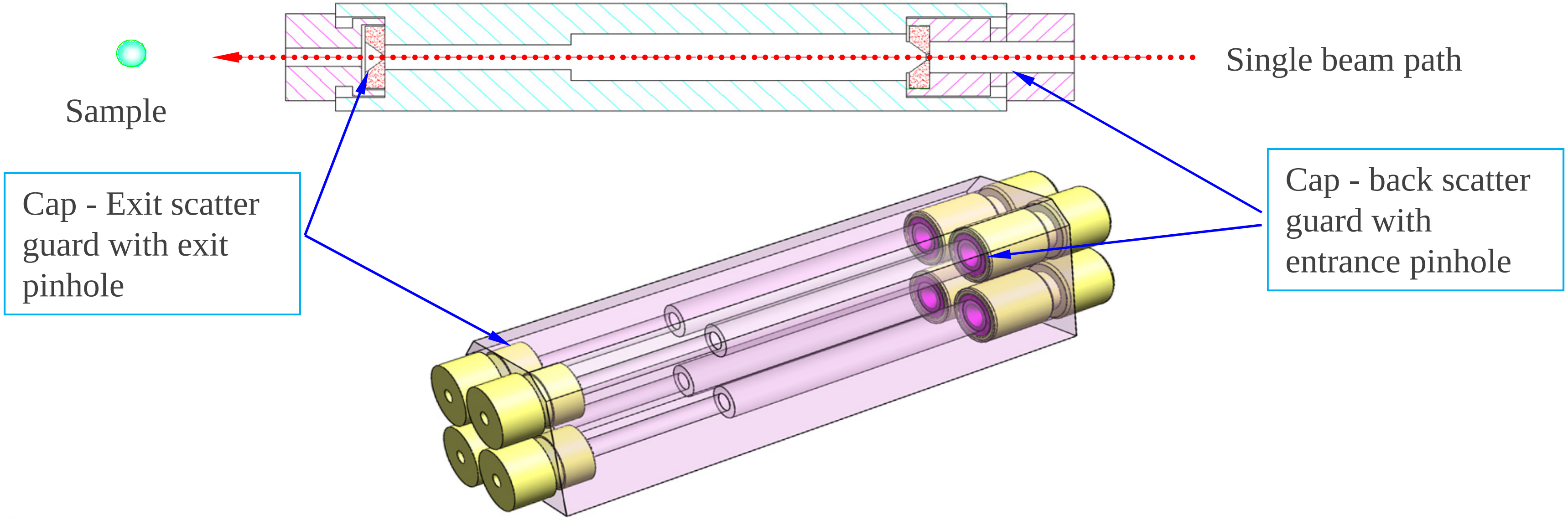
5µm/250µm



Background scattering
Decreased by 60%

Added Exit Cap to Remove Metallic Rings





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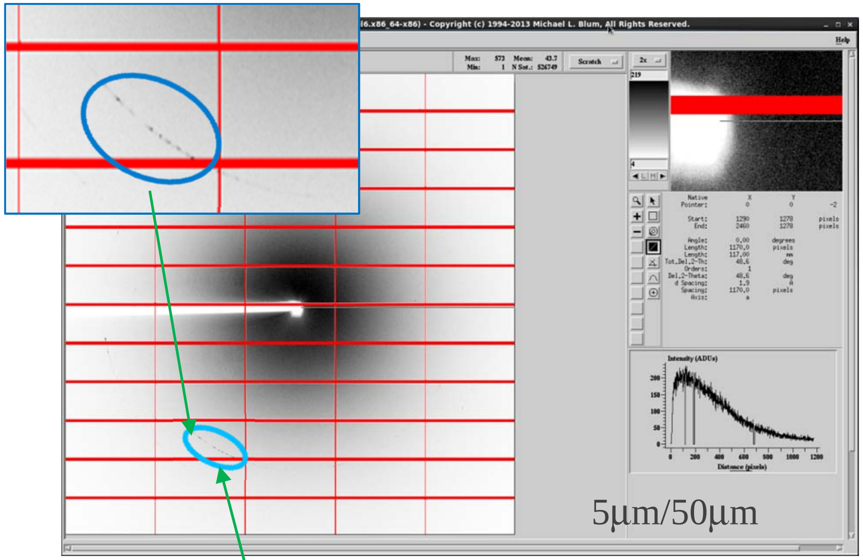
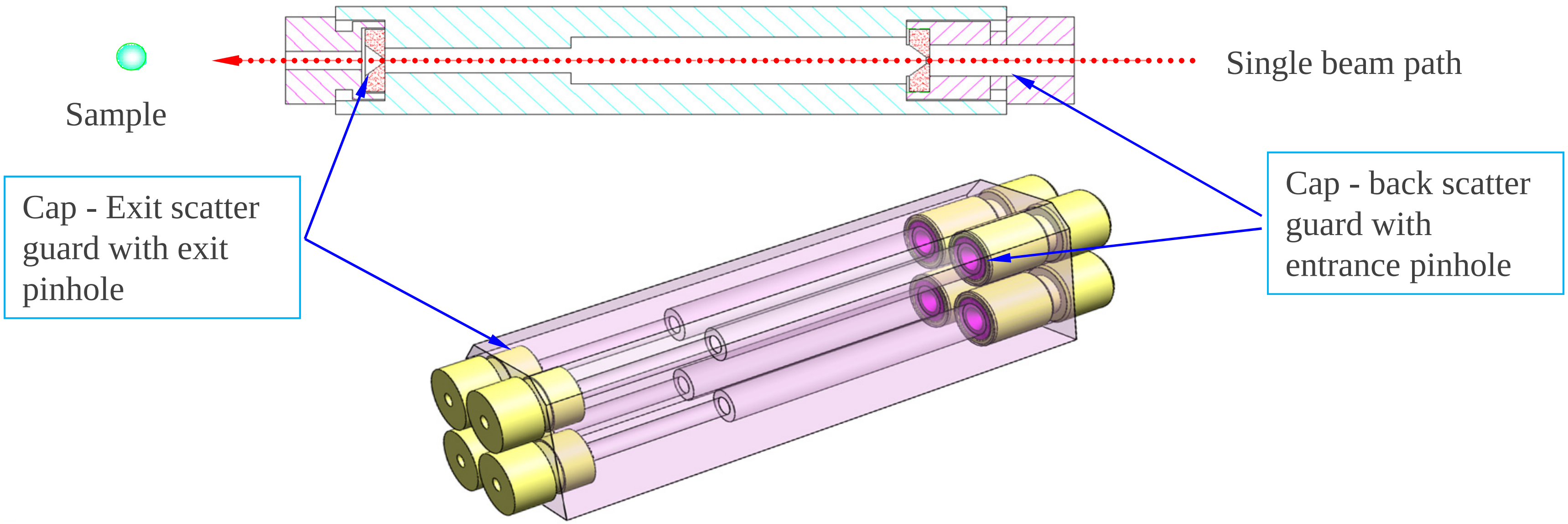


Faint metallic rings escaped exit aperture



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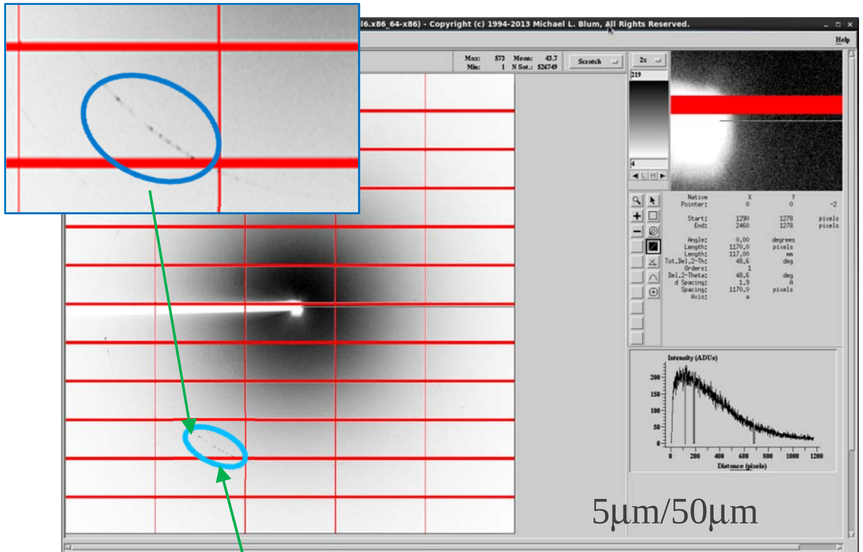

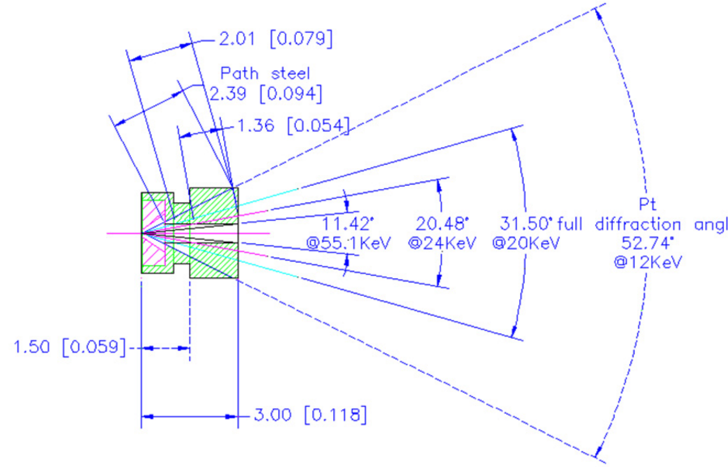

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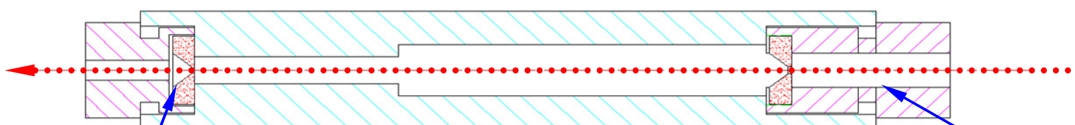
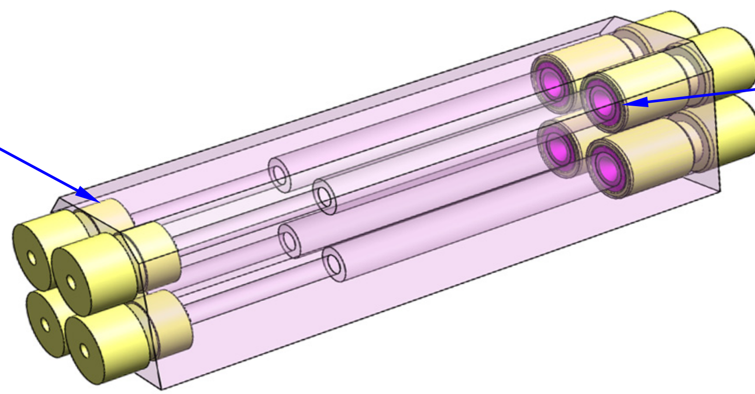


Sample

Single beam path

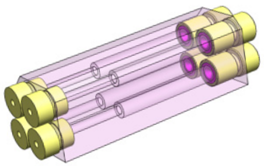
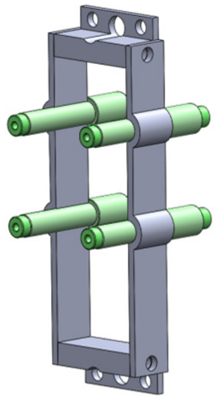
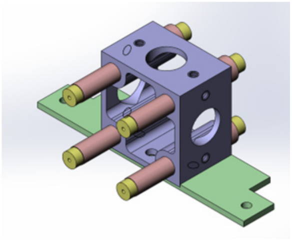
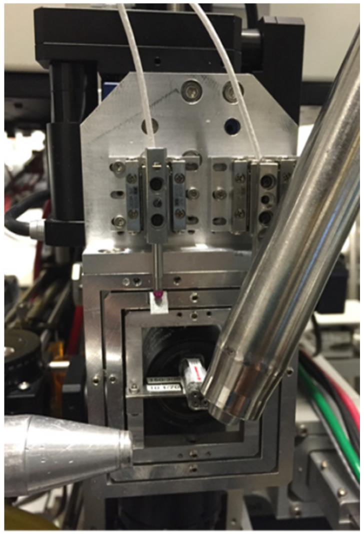
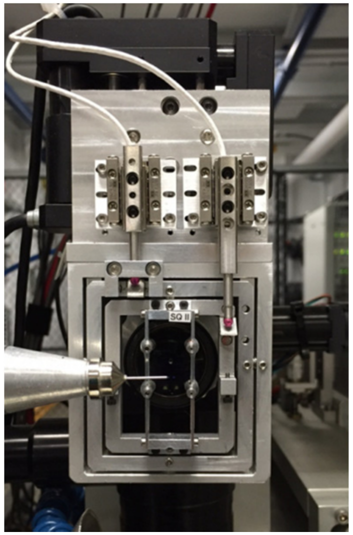
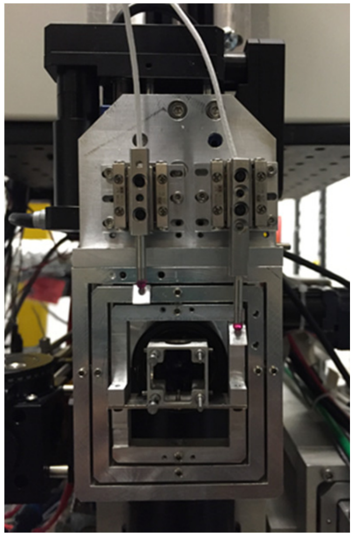
Cap - Exit scatter guard with exit pinhole

Cap - back scatter guard with entrance pinhole

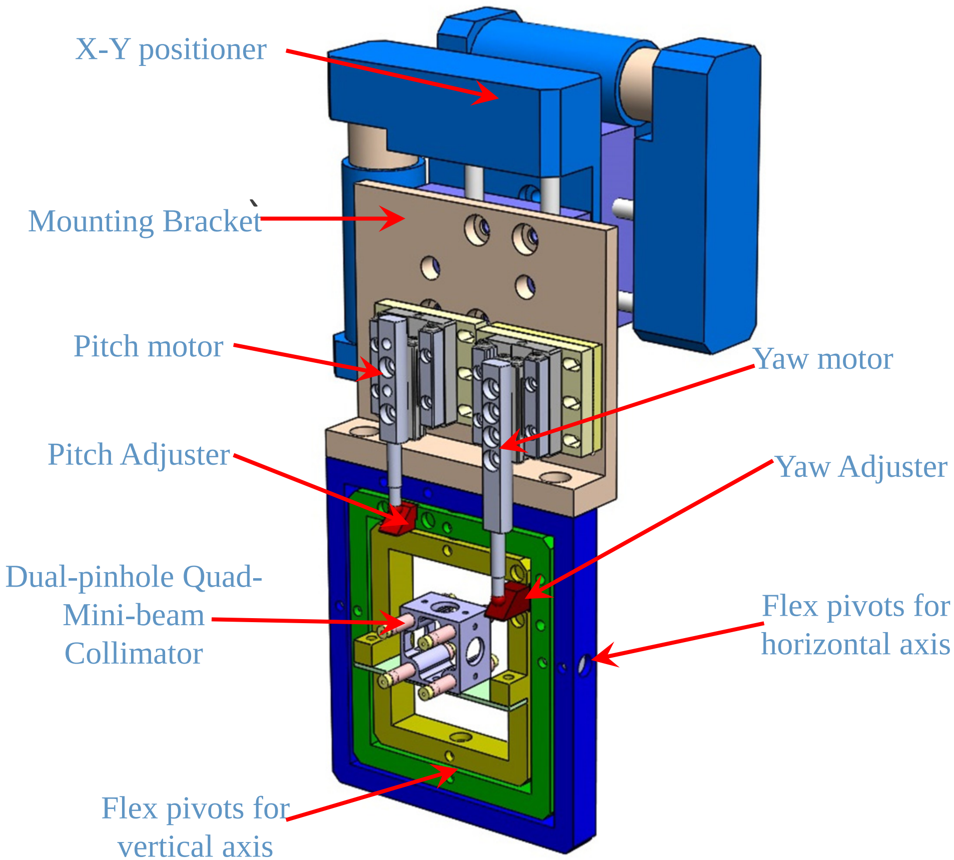


Collimator as installed at the beamline endstation

Beam direction

March 2015	November 2015	April 2016
		
Exit scatter cap	View of sample	Robust
		
	ID-D – Station	ID-B – Station

Collimator positioning system with motorized pitch and yaw adjuster

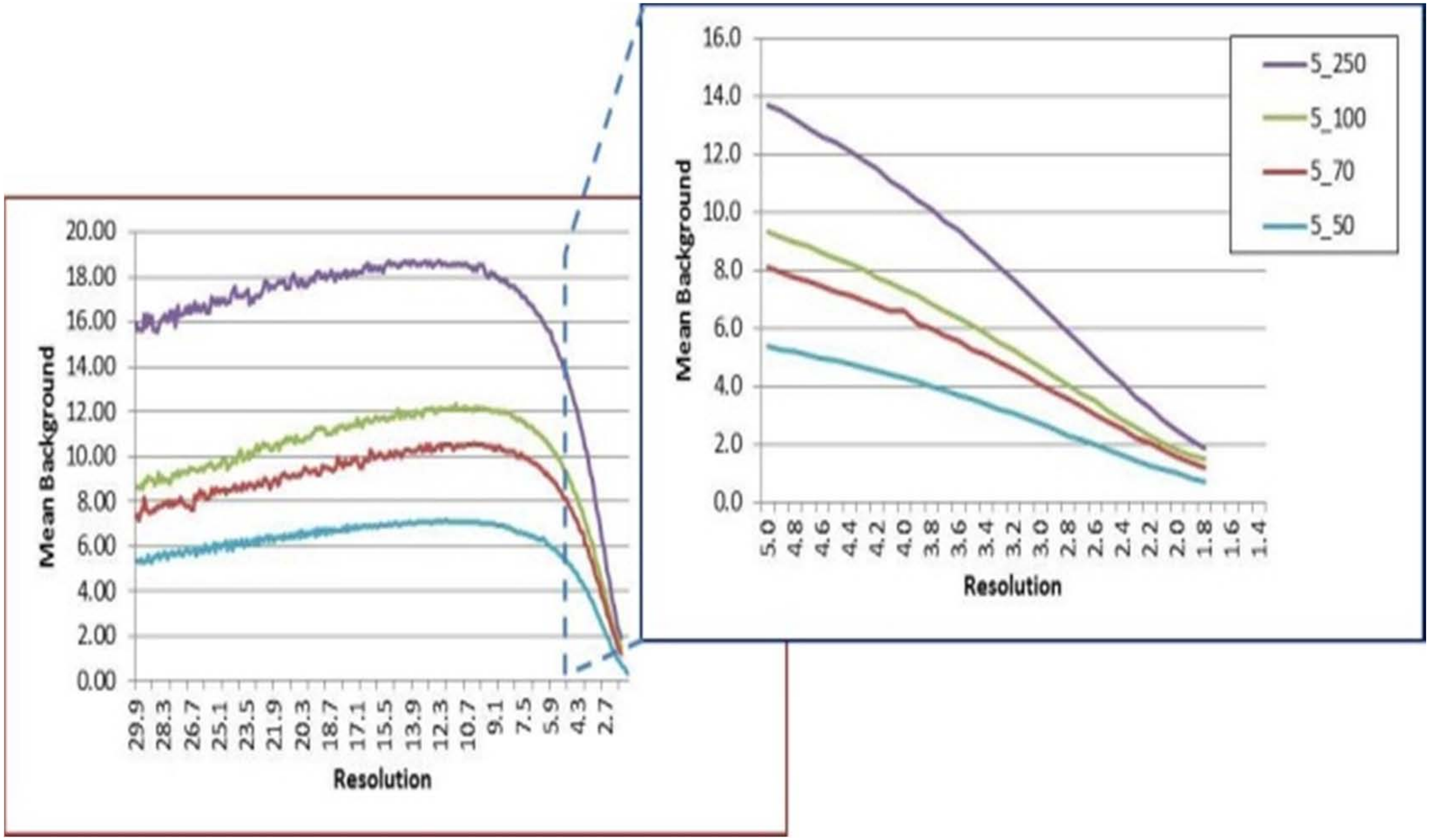


New Quad collimator Alignment

The motorized pitch and yaw motions made alignment of each beam defining/exit aperture combination relatively easy. The two translational and two angular motions were highly reproducible

Independent angular adjustments for each collimator
Translational X and Y positions and angular pitch and yaw are stored
Translational and angular positions recalled to provide desired beamsize.

Conclusion



- Systematic reduction in background as we reduce the size of the exit aperture.
- Over all background reduced by 27% for the full beam (from 300/600 to 150/300).
- Over all background reduced by 60% for the 5mm beam (from 5/250 to 5/50).

Acknowledgements

GM/CA colleagues:

Robert R. Fischetti
Group Leader

Design

Naga Venugopalan
Crystallographer

Design, installation and alignment

Oleg Makarov
Control Systems Developer

Hardware and controls

Sergey Stepanov
Control Systems Sector Leader

Controls and software

GM/CA CAT is funded by the National Cancer Institute and the National Institute of General Medical Science.
The Advanced Photon Source is supported by the U.S. Department of Energy, Basic Energy Sciences, Office of Science


Thank you for your attention!